Nano in the Public Eye

In the mere 18 months since the National Cancer Institute unveiled the Alliance for Nanotechnology in Cancer, its expanded, groundbreaking initiative in nanotechnology, the science and promise of nanotechnology has exploded in the public's consciousness. In the media, at least, nanotechnology has now made the transition from scientific curiosity to full-blown industrial revolution-in-the-making, and the public, by all reports, is optimistic about the role that nanotechnology will play in the next generation of biomedical advances.

President Bush, in his most recent State of the Union address, singled out nanotechnology as deserving the Nation's financial support, and both State and Federal agencies see nanotechnology as a significant driving force for the future economic competitiveness of the United States. For good reason, too – the National Science Foundation predicts that the market for nanotechnology-enabled products, including those to treat cancer and other human diseases, will hit $1 trillion by 2015, and the U.S. leadership role in nanotechnology has it well-positioned to capitalize on this burgeoning market.

And like many breakthrough sciences before it, nanotechnology progresses with turbo-charged speed – already, some 80 products now on the market contain engineered nanoscale materials. But the rapid pace of technological development has prompted questions about both the environmental and health safety of nanoscale materials. In this regard, nanotechnology is not unusual. Novel technologies have often stirred debates on environmental and health safety.

Historically, the advent of major paradigm-shifting scientific discoveries has provoked action by the scientific community itself. For example, when scientists created the first hybrid or recombinant DNA molecule in the early 1970's, there was concern that foreign DNA might be detrimental to the safety of not only the researchers that utilized it, but the public at large. In response to these concerns, scientists came together, realizing that a set of safety guidelines and protocols would ease people's fears. At the Asilomar Conference Center in 1975, researchers, legislators and journalists worked together to get the message out: "We will take care, and you will be safe." In fact, the call by the scientific community for more regulation rather than less both spurred research and reduced uncertainty, leading to the rapid growth and a world leadership position in biotechnology.

Thirty years later, and with modern molecular biology moving into middle age, we know that these socially concerned, scientific pioneers were correct. Indeed, recombinant DNA is not only generally safe, but it has become the cornerstone of modern drug discovery, the backbone behind the large-scale production of everything from the hormone insulin to vaccine components, such as for the Hepatitis B vaccine, to therapeutics like erythropoietin and epidermal growth factor. And while the public still has questions about "Frankenfoods" and "gene doping" to improve athletic performance, and "super-viruses" engineered as weapons of mass destruction, the American public appears to accept that biotechnology is well-regulated and a significant contributor to the U.S. economy and society as a whole.

Taking the Public Pulse on Nanotechnology

Today, the vast majority of scientists, engineers and clinicians involved in nanotechnology research understand that the public is asking the same questions about safety that it asked 30 years ago when genetic engineering

Courtesy: Cornell University, Ithaca, NY

It's a Nano World, developed by Cornell University's Nanobiotechnology Center and the Ithaca, NY, Sciencenter using National Science Foundation (NSF) funding, is a traveling 3,000-square-foot exhibition aimed at reaching 5- to 8-year-olds and their parents.

Courtesy: Cornell University, Ithaca, NY

Since the debut of *It's a Nano World* in 2003, the exhibition has been seen by an estimated three million people during its travels to Epcot Center and science museums around the country.

entered our consciousness. Today's nanotechnology pioneers know that while the research they are doing holds tremendous promise for improving human health, solving the world's energy woes, and cleaning the environment, the public isn't quite sure what to make of the safety of nanoengineered materials. And in large part, that uncertainty arises from a lack of knowledge about nanotechnology in general and what the government is doing to ensure that nanomaterials are safe for widespread use.

"We've found in our work that the more the public has learned about nanotechnology, the more excited they get about it. But at the same time, the more the public learns, the more it expresses concern over the 'dark side' of technology and worries that scientists don't know enough yet about these materials to ensure that they won't cause problems down the road," says Andrew Maynard, Ph.D., a former nanotechnology researcher at the National Institute for Occupational Health and Safety who is now science advisor to the Project on Emerging Nanotechnologies, a joint effort of the Woodrow Wilson International Center for Scholars and the Pew Charitable Trusts.

According to several surveys of the public's opinion about nanotechnology, the public today has little awareness of nanotechnology, but those that do have a generally favorable view and are excited about the potential benefits from nanotechnology research, particularly in the area of medicine. These surveys found, too, that members of the public that are aware of nanotechnology have some concern about health and environmental safety and believe that there should be research aimed at determining which nanomaterials might have risks that outweigh potential benefits.

Perhaps not coincidentally, the NCI found much the same sentiment among the research and clinical communities when it was gathering input for its Cancer Nanotechnology Plan, the guiding document for the NCI's Alliance initiative. Indeed, the NCI's creation of the Nanotechnology Characterization Laboratory (NCL) was a direct response to the scientific community's strong suggestion that biomedical nanotechnology development would benefit from getting ahead of the curve in terms of safety testing.

One report, from the Hubert H. Humphrey Institute of Public Affairs at the University of Minnesota, highlighted similar findings. This report, *The Nanotechnology-Biology Interface: Exploring Models for Oversight*, noted that while the public is hungry for more information about nanotechnology, efforts to educate the public must use communication channels that extend beyond the mainstream media. Indeed, outreach efforts should include venues such as schools, science museums, community groups and local libraries.

Courtesy: Woodrow Wilson International Center for Scholars, Washington, DC

Andrew Maynard, Ph.D., science advisor to the Project of Emerging Nanotechnologies, a joint effort of the Woodrow Wilson International Center for Scholars and the Pew Charitable Trusts.

Taking Action

Leaders from government, the private sector, public interest groups and the scientific community have not been sitting on their hands when it comes to educating the public about nanotechnology nor about taking steps that will identify any risks involved with specific nanomaterials. First, the education front.

The National Science Foundation (NSF), for example, has earmarked $14.3 million to create a network of centers that will focus on nanotechnology's role in and acceptance by society, while five of the eight NCI-funded Centers of Cancer Nanotechnology Excellence have explicit programs aimed at engaging and educating the public and community leaders about nanotechnology. This spring, the National Nanotechnology Initiative (NNI) program office will hold a workshop on public engagement that will examine specific ways of reaching out to the public so that average citizens will want to learn more about nanotechnology and participate in discussions about how best to regulate and monitor nanotechnology-enabled products.

"The National Nanotechnology Initiative recognizes the importance of education and public engagement in the area of nanotechnology," explains Cate Alexander, who serves as communications director for the National Nanotechnology Coordination Office. "Through the NSF and various agencies the Federal government is hoping to stimulate a broad discussion involving the public about potential societal impacts in a way that is educational and productive." She notes that the NCI has been actively involved in the NNI public outreach, having considerable experience in engaging stakeholder groups.

Using NSF funding, for example, Cornell University's Nanobiotechnology Center and the Ithaca, NY, Sciencenter have developed a traveling 3,000-square-foot exhibition, *It's a Nano World*, aimed at reaching 5- to 8-year-olds and their parents. Since its debut in late

2003, *It's a Nano World* has been seen by an estimated three million people during its travels to Epcot Center and science museums in Ohio, South Carolina, Louisiana, Michigan, Virginia and Texas. Cornell and the Sciencenter are now testing a second exhibition, *Too Small To See*, that was designed to reach children 8 to 13 years old and their parents.

Courtesy: Siteman Center for Cancer Nanotechnology Excellence, St. Louis, MO

Paula Fracasso, M.D., Ph.D., oncologist at the Siteman Center for Cancer Nanotechnology Excellence (SCCNE) in St. Louis.

At the Siteman Center for Cancer Nanotechnology Excellence (CCNE), in St. Louis, oncologist Paula Fracasso, M.D., Ph.D., leads a multi-pronged effort that seems typical of the outreach programs planned by the CCNEs. "Our goal is to reach a wide audience, including physicians and the general public, using a variety of communications channels that we already have established here at Siteman Cancer Center," she explains. Among these channels are newsletters and monthly programs that reach community leaders; a variety of health and wellness events for the public, including the annual Susan G. Komen Race for the Cure; the Cancer Patient Education Network; and the widely attended Women in Science program that the cancer center sponsors.

The St. Louis Science Center, in the midst of remodeling, has approached Fracasso and her colleagues about providing input for a new nanomedicine exhibit that would appear on the museum's first floor. "We have real opportunities available that could enable us to reach a good cross-section of the public, provide them with factual information, and help ease any fears about nanotechnology," says Fracasso. "We have to succeed at this effort if we want to avoid a backlash against this promising set of technologies."

Addressing the Safety Issue

The public's other main concern has to do with the safety of nanoscale materials, and here the challenge for nanotechnology is significant. "The field of nanotechnology is so broad, and there are so many different types of nanomaterials available, that there's the potential to be paralyzed by the sheer enormity of identifying which of these materials are safe and which might have problems," says Maynard.

"The thing you have to remember," he adds, "is that humans are constantly exposed to large quantities of nanoparticles, in the form of dust and other natural materials, as well as to manmade materials such as diesel exhaust. The issue, then, is not that these are nanoscale materials, per se. The issue is that today's nanomaterials have been engineered with very specific properties, and what we don't know yet is how to separate those few properties that are going to lead to toxicity and the majority of which are not going to cause problems. The flip side of this, though, is that trying to sort out the good from the bad leads to very interesting scientific questions that we can address, and that indeed, have really captured the interest of the toxicologists and biologists and engineers."

Nigel Walker, Ph.D., who heads the nanotoxicology effort at the National Toxicology Program (NTP), confronted the problem of where to start when he was first approached three years ago by Vicki Colvin, Ph.D., who heads Rice University's Center for Biological and Environmental Nanotechnology. "I was talking with Vicki and her colleagues at Rice and they were concerned that if the Federal government didn't start testing nanomaterials soon, that we could have the type of backlash against nanotechnology that genetically modified foods are experiencing today," says Walker. "After that meeting, we at the NTP started looking at what nanomaterials were available and realized that we couldn't possibly look at each one of them."

Instead, Walker decided to focus his program on several of the major classes of materials under development, including quantum dots, fullerenes, nanotubes, and metal oxide nanoparticles. He also decided to stay away from materials that were designed exclusively for biomedical applications because those materials, like any other potential drug or diagnostic agent, would have to pass the rigorous safety tests designed in order to gain approval for use in humans from the U.S. Food and Drug Administration (FDA).

Walker made an exception for sunscreens, which like other cosmetics, are not regulated by the FDA. "The other issue with nanoparticle-based sunscreens is that there is a significant public exposure issue here – people are going to be putting this material on their skin in significant amounts." In contrast, he added, most nanomaterials intended for use in humans will be used in such small quantities that exposures will be small.

Courtesy: National Toxicology Program, Washington, DC.

Nigel Walker, Ph.D., of the National Toxicology Program (NTP).

The NTP nanotoxicology effort is also working closely with the NCL. "The NCL is focused on toxicities that might arise with the relatively short-term, relatively high-dose exposures you get from taking a drug, while we're concentrating on chronic exposure to relatively low doses of nanomaterials such as you might get at work or out in the environment," explains Walker.

The NCL, in turn, is collaborating with both the National Institute of Standards and Technology (NIST) and the FDA to develop standardized methods for characterizing the physical properties of a particular nanomaterial and assessing potential toxicities. "Characterization helps us understand the relationship between structure and activity," explains Scott McNeil, Ph.D., director of the NCL. "When we get something that is either biocompatible or toxic, we can ask, 'what makes this particle good or bad?' Is it the size, the charge distribution over the molecule, the surface chemistry? Another important goal is that of reproducibility. We're developing these assays in order to compare data from lab to lab, and to allow for research to be more rapidly commercialized."

Projects such as these get high marks from observers such as Maynard. "It is encouraging that the Federal government has established these efforts before there was a public outcry for them," he says. "Could there be more support for this type of research? Yes, I have no doubt, but what is needed more than more money at this point is a strategy for answering safety questions. Right now, aside from those at the NCL and perhaps the NTP, I'd say our efforts are a little random at this point, but I believe the interest is there among the research community to do this right. The public is asking for this information, and we need to provide it or risk all sorts of acceptance problems down the road." <

—Joe Alper